Sustainable Gastronomy: The Environmental Impacts of How We Cook Now and How Might the Sustainable-Diets Agenda Shape How We Cook in the Future?

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Abstract: The 2019 Eat-Lancet report has proposed a global healthy sustainable diet, which would provide not only for human health but also sustain a healthy planet. The main recommendations are to increase consumption of healthy foods (such as vegetables, fruits, whole grains, legumes, and nuts), and a decrease in consumption of unhealthy foods (such as red meat, sugar, and refined grains).

A critique of the EAT-Lancet diet is that it lacks consideration of local and traditional diets, food ways or systems of production, and the report has limited suggestions for how a global healthy sustainable diet could be implemented (Edman et al., 2019; Jonas, 2019; Torjesen, 2019).

This paper firstly explores the sustainability impacts of cooking food, and how different foods have different environmental impacts from production, consumption, and cooking. It reports on a 2019 survey of cooking methods and habits in the UK, Australia and USA, examining how these different nations' unique culinary and cooking habits lead to different environmental impacts. This paper then examines what dietary shifts are being recommended by current academic literature, and how these dietary shifts may change the methods of cooking in the future.

The global food system accounts for 30% of greenhouse gas emissions (GHGE) (Mbow et al., 2019). Changing methods of food production and consumption have been shown to be one of the many ways to effectively reduce our carbon emissions and combat climate change (Hawken, 2017).

Many (myself included) have suggested that part of this move to a lower carbon food system, should include the adoption of a healthy sustainable diet by all (Aleksandrowicz et al., 2016; Green et al., 2015; Macdiarmid et al., 2012; Perignon et al., 2017; Reynolds et al., 2019, 2014; Rust et al., 2020; van Dooren et al., 2015).

One version of this global healthy sustainable diet can be found within the EAT-Lancet report (Willett et al., 2019). The EAT-Lancet report was the first full scientific review of what constitutes a healthy diet from a sustainable food system. It is the result of a global collaboration of 37 world-leading scientists attempting to answer the question: 'Can we feed a future population of 10 billion people a healthy diet within planetary boundaries?' The report proposed a global diet that would provide not only for human health but also sustain a healthy planet. The main recommendations are to increase the consumption of healthy foods (such as vegetables, fruits, whole grains, legumes, and nuts), and decrease the consumption of unhealthy foods such as red meat, sugar, and refined grains.

However, there has been much online backlash of the EAT-Lancet diet, with critics stating that it lacks consideration of local and traditional diets, food ways or systems of production, and the report has limited suggestions for how the suggested global healthy sustainable diet could actually be implemented (Edman et al., 2019; Garcia et al., 2019; Jonas, 2019; Torjesen, 2019).

In my previous paper, *Sustainable Gastronomy; power and energy use in food – is it possible to fight climate change though cookery?,* presented at the 2019 Oxford Symposium on Food and Cookery (Reynolds, 2019), I established that the production and consumption of food is linked to the generation of greenhouse gas emissions (GHGE), and that energy (electricity) is used in the production of food and also in cookery. When this energy is generated from environmentally damaging sources, such as coal and gas, it also is linked to greenhouse gas emissions. I then examined how the choice of cooking method and the time spent cooking is related to the exact amount of energy used, and the resulting climatic impact. (1)

In the Oxford Symposium paper, I then reviewed the history and content of sustainable cookbooks, highlighting 23 key texts. These range from Frances Moore Lappé's *Diet for a Small Planet* (Lappe, 1992), through to contemporary texts such as Diana Henry's *Plenty: good, uncomplicated food for the sustainable kitchen* (Henry, 2010), or the five books of the American Academy in Rome's *Sustainable Food Project* (Talbott, 2012, Boswell, 2013, Boswell, 2014, Talbott and Misenti, 2010, Behr, 2016). Since the Oxford Symposium, I have been alerted to additional sustainable cookbooks such as Rose Princes' *The New English Table: Over 200 Recipes That Will Not Cost The Earth* (Prince, 2010), and Frank Holleman's self-published *Fork Ranger – Solving Climate Change with Food* (Holleman, 2019).

I have found sustainable cookbooks to be a broad genre. There is a variety of vegan, vegetarian, and omnivorous books published, each with different concepts of sustainability or low-carbon diets (some containing beef or lamb). The main commonality is that each ask the reader to change their behaviour and embrace differing concepts such as using leftovers, shopping organic, buying local, mindful eating, and/or eating seasonally. However, within the cookbooks surveyed, the environmental benefit these actions will have at an individual level is not quantified. Indeed it is only within the last decade that this quantification has been done within the scientific literature. Likewise, few consider the impact of cooking

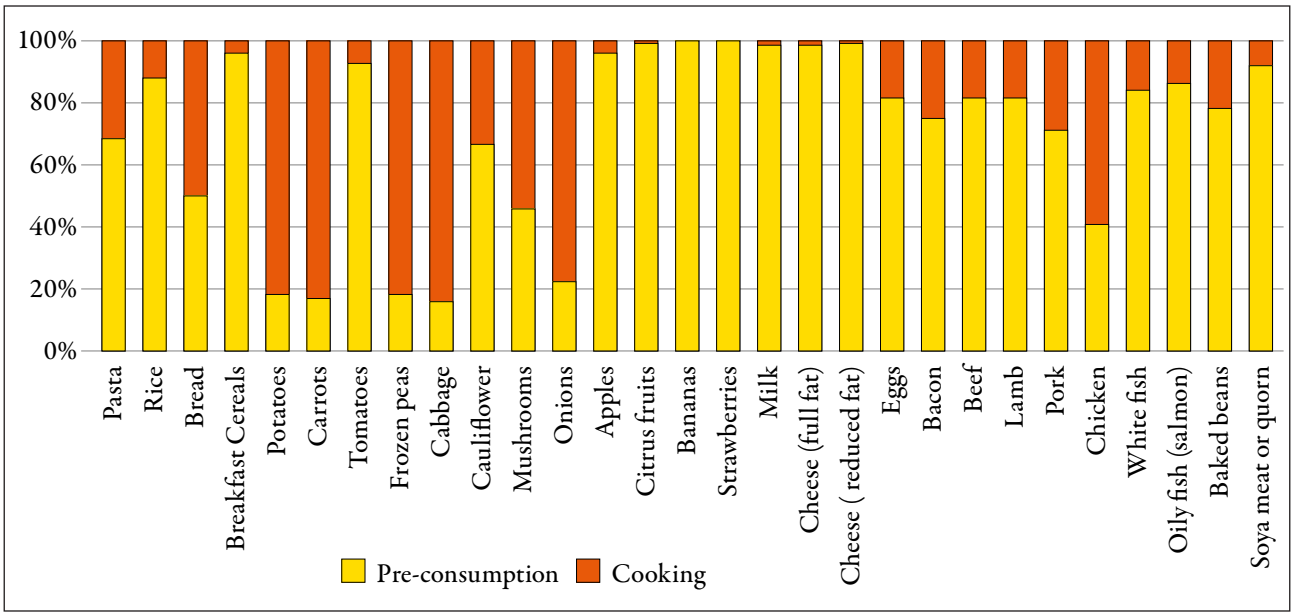

Figure 1. Greenhouse gas emissions (%) apportioned to cooking or pre-consumption impacts from Frankowska, et. al. (2019).

method, and none exclude baking or roasting, which as we will see below are methods related to high emissions.

In this paper I wish to further promote my argument. First, I will report the outcome of survey work presented at the 2019 LEAP conference (Frankowska et al., 2019). This pilot survey measured the GHGE impacts of changing cooking methods for 30 food items commonly consumed in the UK as part of a wider UK, USA, and Australian survey. In this paper, I will report some of the findings, comparing cooking methods across the three countries. This evidence shows that even three similar western diets have differences in popular cooking methods. With the addition of this new knowledge, I wish to re-examine how the current sustainable diets debate might in time influence how we will cook food in the future.

How do UK cooking methods contribute to climate change?

The GHGE impact of cooking changes with the food cooked and the method of cooking used. Many previous estimates have attributed the proportion greenhouse gas emissions from cookery at up to 30% to 50% of total greenhouse gas emissions for some foods (Carlsson-Kanyama and Boström-Carlsson, 2001; Defra, 2008b, 2008a; Mattsson et al., 2005; Reynolds, 2017a, 2017b).

However, there has never been a comprehensive list of multiple foods and cooking methods established. My wider research group has endeavoured to conduct pilot research to fill this gap. In Frankowska et al., (2019) we selected 30 food items commonly consumed in the UK, and conducted an online UK wide survey of cooking habits and food practices (n=397, with data cleaning). From this we gathered the cooking methods (appliances) and practices (times) associated to each food item. We then built a database of energy consumption of UK cooking appliances. When the type of fuel was not specified (i.e. hob), UK average data was used (e.g. distribution of electric and gas hobs in the UK) (DECC, 2013). Energy consumption was calculated per food item using the collected cooking method and practices. The environmental impacts of cooking, reported in kilograms of CO_2e (2), were calculated using the carbon emissions factor for the UK electricity mix and natural gas for the year 2019 (DBEIS, 2019). To then estimate the contribution of cooking to the environmental impacts of food, data of the environmental impacts of each food item at pre-consumption stage was sourced from literature (Poore and Nemecek, 2018).

We found that cooking contributes significantly to the overall impact, ranging between 8%-84% of emissions (Figure 1). For vegetables, cooking is an important part of GHGE, accounting for 33%-84%. In the case of meat, the cooking shows notable impact contribution to between 20%-60% to the total. The absolute overall emissions (farm to home plus cooking), however, the highest for meat products are multiple times greater compared to vegetables and starchy products. Thus the footprint of meat (including cooking) is still higher, than that of vegetables even after adding the larger cooking impacts of vegetables.

However, because each cooking method has an impact on climate change depending on the cooking time, it is possible to change the type of cooking method, and the duration to shift to a lower carbon footprint. Figure 4 below shows GHGE of different foods, demonstrating the relationship of various preparation techniques and the average cooking time used.

Meat, such as beef, is mainly roasted or baked in the oven as well as fried on the stove. Roasting or baking in the oven is the environmental worst cooking option since long cooking times are required, increasing emissions more than three-fold compared to frying on the stove.

Heating up baked beans is more sustainable using the microwave compared to the stove as emissions are halved

	United Kingdom	Australia	United States
Refrigerator	92	97	93
Freezer (ex. Freezer compartment at top of fridge)	86	68	62
Microwave oven	85	89	84
Electric hob (ring)	46	31	16
Gas hob (ring)	49	41	13
Oven	88	91	80
Kettle	89	91	25
Sous vide machine	3	2	2
Toaster	84	88	73
Slow cooker	50	61	63
Pressure cooker	17	27	24
Food processor	38	44	29
Electric grill (such as George Foreman)	37	32	25

Figure 2. Percentage of kitchen equipment ownership for the United Kingdom (n=676, 65% female), Australia (n=503, 63% female), and the United States (n=894, 75% female).

despite nearly equal cooking times. Likewise, in the case of frozen peas, using the microwave emits the least GHGE, while steaming causes the highest emissions. Boiling reduces the impact by a quarter compared to steaming which is also related to the lower cooking times.

In the cleaned UK subsample, Potatoes were boiled by 50% of respondents, while 30% roast their potatoes in the oven and 5% prepare them in the microwave. Potatoes cooked in the microwave are responsible for the least GHGE, followed by boiling, while roasting them in the oven results in higher emissions by two-fold and four times, respectively.

Method: A survey of current cooking habits in the UK, Australia and the USA

The Frankowska et al., (2019) study reported the cleaned UK subsample from an online survey about of cooking habits and food practices. The full online survey was conducted from March to April 2019 across the UK (n=676, 65% female), USA (n=894, 75% female) and Australia (n=503, 63% female). This online survey used the Qualtrics survey platform and country panels. The surveys were sampled to be semi-representative of age in each country, however due to online recruitment, these were not representative along gender lines and require cleaning before in-depth analysis can be carried out. The surveys asked questions about demographics, food perceptions, cooking habits and food practices for 30 food items commonly consumed in the modern western diets.

Results

Below, I present some results of this wider (uncleaned) survey to show the current diversion of cooking environments and habits between UK, USA and Australia (Figures 2 and 3), and also the results of the Frankowska et al., (2019) study (Figure 4) to show the potential of changing cooking methods to reduce emissions by harnessing these divergences.

Figure 2 compares kitchen equipment ownership across the UK, USA and Australia. This shows that though all three countries can be considered to be in the western cuisine style with over 80% microwave ownership. There are differences in the equipment owned in these countries. For instance, only 25% kettle ownership in the USA. These differences in access to equipment influence the cooking methods used.

Figure 3 compares the typical cooking method of a sub-sample of 4 of the 30 common foods: potatoes, carrots, beef and chicken. This shows there are divergent trends in cuisine styles and cooking practices with the UK and Australia more typically boiling potatoes, while in the USA roasting potatoes is of equal popularity. Likewise, roasting chicken and beef in the UK is the most popular method while in Australia and the USA frying on the stove has greater popularity.

Figure 4 shows that there are changes to cooking method that can make meaningful (80%+) reductions in the emissions related to cooking, and that these can also make reductions to the overall emissions related to food. Indeed, GHGE can be reduced between 40% and more than three-fold by avoiding cooking in the oven and choosing preparations methods that require less cooking time. This highlights that 1) each country will have different cooking impacts due to its unique cooking habits, and 2) each country has different pathways to adopt sustainable diets and cooking due to its wider food environment (equipment, food choice etc.

Discussion: Disrupting eating (and cooking) for lower carbon emissions

Discussion of cooking's impacts have been missing from the current healthy sustainable diets debate. Instead,

	Potatoes			Carrots			Beef			Chicken		
	United Kingdom	Australia	United States	United Kingdom	Australia	United States	United Kingdom	Australia	United States	United Kingdom	Australia	United States
Shallow fry on stove	3	3	9	3	5	6	10	36	22	12	30	15
Deep fry	4	6	9	1	3	4	4	5	6	6	6	11
Roast or bake in oven	27	30	27	8	15	10	42	25	29	47	34	36
Steam	6	5	4	19	23	17	5	2	5	4	3	5
Boil on the stove	43	41	26	48	31	22	4	5	6	4	4	5
Microwave	5	8	7	5	8	8	2	1	4	4	2	3
Toast, broil or grill in oven	4	2	4	2	2	2	5	4	5	6	4	7
Sous vide	1	0	1	1	0	1	1	2	1	1	1	1
In a slow cooker	1	2	3	2	1	4	7	6	5	4	3	4
In a pressure cooker	1	0	2	1	1	1	2	3	3	1	1	2
Eaten as purchased	2	1	2	6	7	15	2	1	2	2	3	2
Do not eat	3	2	5	3	3	7	14	7	8	8	6	7
Use an electric grill	0	1	1	0	1	1	3	4	4	2	3	2

Figure 3. Typical cooking method (percentage) for potatoes, carrots, beef and chicken for the United Kingdom (n=676, 65% female), Australia (n=503, 63% female), and the United States (n=894, 75% female).

sustainable dietary advice has previously focused upon 1) reducing the instances of consumption (number of times animal products are eaten) and 2) reducing the portion sizes of animal products. Both of these are to achieve the end result of following EAT-Lancet recommendations: 0-28g per day for beef, lamb or pork, and 0-58g per day for chicken and other poultry, and 0-100g per day of legumes, and 0-100g per day of starchy vegetables. As a typical beef portion in the UK is between 70-90g, to align this with the EAT-Lancet guidance this might imply that beef may be cooked once per week as a standalone protein source, or that protein sources are mixed into other dishes to spread lower quantities of animal products throughout the weekly diet.

This first option (smaller portion sizes of cuts of meat) has been shown in my previous work (Reynolds, 2017a) to have some capacity for reduction of carbon emissions. However, roasting a small portion of meat – even once a week, contributes to a large impact. Indeed, the smaller the portion, the larger the cooking impact per gram. This implies that if we are to eat cuts of meat, and to cook them with low emissions we need to fry or use other lower emission techniques such as slow cooking, pressure cooking, sous vide cooking, etc.

To embrace this second option (smaller quantities of animal protein integrated into other dishes) may imply stopping the traditional roasting or boiling of meat, and adopting a more Asian or African style of cooking (stewing or fast shallow frying). However, I argue that there are examples of these dishes and cooking methods that appear in western cooking cultures. So we might understand this

change as either an adoption of new cuisines, techniques, and styles; or as a move towards more historic cooking, that featured these cooking methods and ingredients. Indeed, I argue that most global food cultures feature a classic or traditional stew be it a scouse, cassoulet or hotpot. However, the popularity (frequency of consumption) and exact recipes (amount of meat) has increased over the last 100 years with the advent of kitchen technology, increasing incomes, and the lowering in the price of meat. We need to shift our diets, moving back towards historic smaller portions of meat combined with modern cleaner low carbon cooking.

Current dietary survey data suggest that the above dietary change options are not being embraced by the public. However, there is a third option: modifying the current trajectory of contemporary popular western food culture – including increasing consumption of (ultra-) processed meat products, burgers and sausages. To do this we need to adapt the popular (ultra-) processed foods to be lower emissions. One option may be to blend minced or ground meat with mushrooms, lentils, or other plant-based protein to reduce total emissions (Waite et al., 2018). We can also adapt the cooking methods of these foods, reducing oven use, and increasing frying. Finally, we can increase the number of portions cooked in one instance – encouraging batch cooking, and leftover (re)use.

So far I have framed these disruptions to the eating and cooking with an immediate onus on changing individual choices and practices. However, these disruptions also lend themselves to wider food system disruption. I argue that the larger food producers and supermarkets have a greater ability to shape environmental change than they give themselves credit for. Changing recipes, instructions, packaging and portion sizes all can have wider effects than individual actions.

Equipment manufacturers also have a role to play in producing and promoting low impact cooking. The use of the microwave (and the pressure cooker, slow cooker and sous vide) has been shown in other research to further reduce the emissions related to cooking (Reynolds, 2017a). Though these do not feature heavily in contemporary western cuisines, the popularity of these cooking styles is growing. The use of the microwave for reheating of premade meals has rapidly grown since its introduction in the 1960s, and cooking in the microwave has also grown. (If reheating can be counted as a form of cookery is another debate). Likewise, the adoption of domestic sous vide is occurring (slowly) with only 1-3% of those surveyed in each country now owning a sous vide machine. Indeed, the in-home adoption of sous vide may also be stalling due to issues around plastic pollution caused by this cooking method. On the other hand, even though pressure and slow cooking features in other global cuisines (such as Brazil, India etc.), only 16% of those surveyed in the UK had a pressure cooker (25% in AU and USA), and 51% a slow cooker (61-62% in US/AU). Professional chefs also need to rethink their biases toward specific methods of cooking if restaurant meals are to also to become more sustainable.

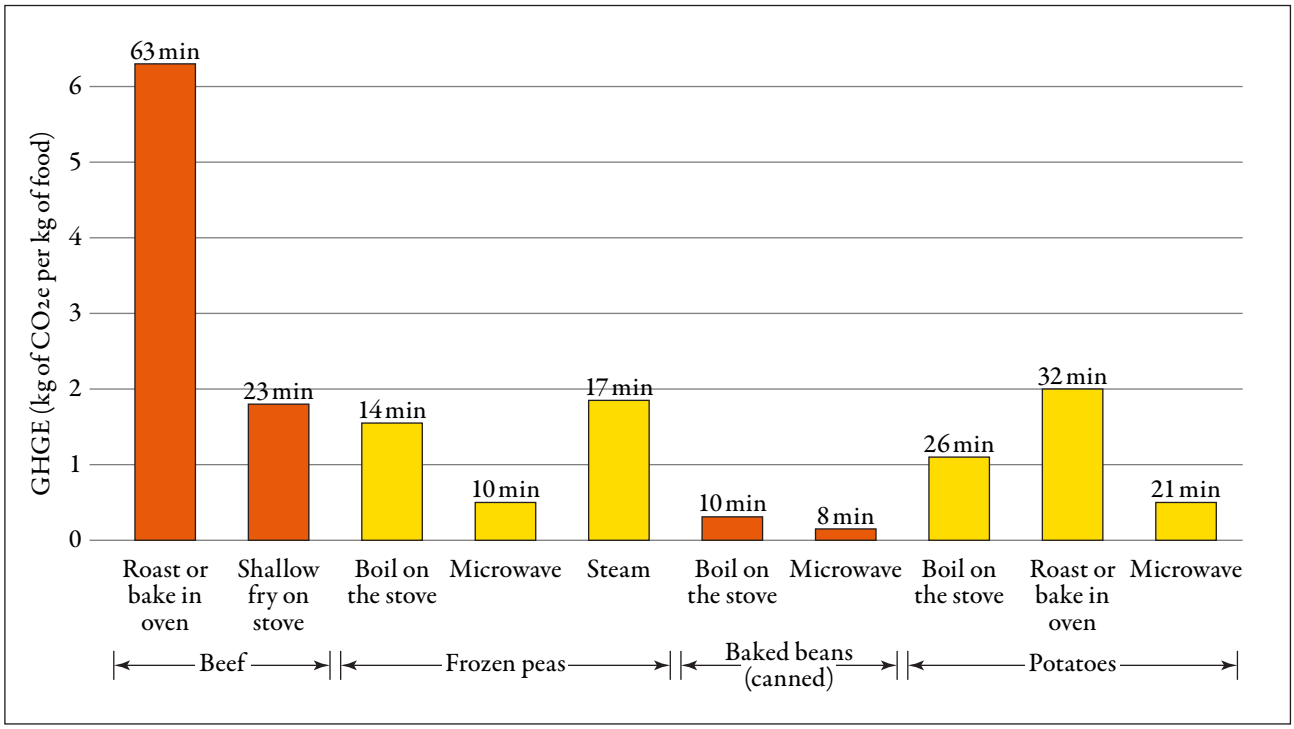

Figure 4. GHGE (kg of CO_2e per kg of food) of different foods, showing the relationship of various preparation techniques and the average cooking times used in the UK, from Frankowska et al., (2019)

Conclusion

In summary, the healthy sustainable diets agenda has begun to inform cookbooks and general public discourse, but it has not yet changed the way we cook. I have offered multiple gastronomic evolutionary paths that future cuisine styles may take. Possible disruptions to cooking and eating habits may include embracing older traditions, more multi-cultural cuisines, and/or new technologies. One certainty is that oven cooking needs to be reduced if there is only one item being roasted (and if there are no efficiency gains). Indeed, if we are to continue to use ovens, there must be multiple items being cooked at the same time to disperse the impact. Likewise, new lower carbon cooking methods need to be adopted by wider society. This may represent dramatic disruption to current popular western cuisine; transforming how things are cooked, and what is eaten. This might lead to a more homogenous global gastronomy, or a plethora of culturally appropriate local gastronomies that have adapted their cuisines to the needs for sustainability and health. Indeed, this is dietary disruption we must embrace, with the climate change consequences for not doing so being much more transformative, and dire in the long term.

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Notes

1. I have previously illustrated this further by showing how cooking a single meal using different methods and cooking times can have different environmental impacts (Reynolds, 2017a).
2. 'Carbon dioxide equivalent' or 'CO_2e' is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2 which would have the equivalent global warming impact.

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